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# MODERN TECHNIQUES APPLICABLE TO THE DESIGN AND CONSTRUCTION OF STRUCTURES FOR SURFACE WATER USING LOCAL MATERIALS AND LABOUR

By Shri C. L. HANDA, I. S. E.,
Member Designs and Research,
Central Water and Power Commission

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# MODERN TECHNIQUES APPLICABLE TO THE DESIGN AND CONSTRUCTION OF STRUCTURES FOR SURFACE WATER USING LOCAL MATERIALS AND LABOUR

BY

Shri C.L.Handa, I.S.E.,
Member (Designs and Research)
Central Water and Power Commission.

## INTRODUCTION

1. India has a gross geographical area of about 811 millio acres. The average annual rainfall is below 50 inches and in most parts this rainfall is concentrated in four months from June to September. As a result, all the surface water tends to run of into the sea in the form of floods. Under these conditions, the most economical and effective method of utilising surface water is by constructing river structures for storage and diversion. Such structures have been constructed in India from ancient times. The Grand Anicut across Cauvery River in Tanjore(S. India) built some time in the 10th century is an outstanding example.

2. The total annual flow of all the rivers in India is estimated to be about 1350 million acre feet, of which about 430 million acre feet is considered economically utilisable for beneficial use. The corresponding potential for hydro-power development is about 41 million kilowatts. Out of these resources, the actual utilisation upto a decade ago was only 76 million acre feet of water for irrigation and an installed hydro-power capacity of 0.5 million kilowatts. The exploding population and the relative backwardness of the country called for a rapid development of its available resources. A series of five year plans for the organised and rapid development was embarked upon in 1950-51. By a judicious utilisation of modern developments in design and construction techniques adapted to the availability of men, materials and construction equipment, we have been able, by the end of 1961 to utilise an additional 36 million acre feet of water for irrigation and instal an additional power capacity of 1.4 million kilowatts. The most important techniques and features which have been made use of are described in the following paragraphs.

## WEIRS AND BARRAGES

3. Weirs are about the cheapest methods for diversion of river waters. Major weirs were constructed during the end of the

last century. The weirs across the Sutlej, Ravi, Ganga, Jumna, Cauvery, Krishna, Godavari and Mahanadi are outstanding examples. However, these have the disadvantage of obstructing the waterway, which particularly affects the regime of alluvial rivers. In such cases, a gated weir popularly known as barrage with the sill of the weir almost at river bed is now preferred. The advantage is that high enough pond levels are possible with limited afflux and less interference with the natural regime of the river. Outstanding examples of this type of construction are Kosi Barrage (3760 ft. long), Nangal Barrage (2700 ft. long) and Durgapur Barrage (2270 ft. long). The salient technical improvements in the modern weirs and barrages are the use of reinforced concrete floors (to reduce thickness and consequent dewatering), improved profiles based on hydraulic models to increase discharge coefficient and stabilise the jump, provision of sheetpile cutoffs and relief wells, and reverse filters for protection against piping, and use of comprehensive hydraulic models to evolve and test designs.

4. An associated problem with water diversion by barrage structures is the exclusion of excessive sediment from the water so diverted. In addition to adopting the conventional methods of utilising flow curvature and providing stilling pockets with undersluices and divide walls, extensive use is now made of silt excluder tunnels and sand extractors or ejectors. The design of these excluder and ejectors are decided on the basis of hydraulic model experiments to suit individual cases.

5. The use of hydraulic models with mobile beds and vertically exaggerated scales is another technique being used for the study of river structures. The interpretation of the model behaviour has to be done carefully keeping in view the inability of model to adjust to variable conditions, the effect of rigid structures on exaggerated vertical scale etc. The improvements in design envisaged on the models have been largely substantiated, and realized in the prototype structures which have been constructed. The technique has become a powerful and in fact an indispensable tool in the designs of river structures.

DAMS

6. Though the construction of major dams in India commenced in the 17th century(Periyar 176 feet high), (Khadakwasla 130 ft.), the largest dam existing prior to the commencement of the five year plans was Mettur with height of 231 feet and having a capacity of 2 million acre feet. Since then some large dams have been completed or are under construction. Bhakra (740 ft. high, 7.4 m.a.ft. capacity), Nagarjunasagar (370 ft., 9.3 m.a.ft.) Rihand (296 ft., 8.6 m.a.ft. capacity), Gandhisagar (212 ft. 6.85 m.a.ft.) and Hirakud (200 ft., 6.6 m.a.ft.) are some outstanding examples.

7. Where concrete has been used for major dams, modern construction methods have been followed. Concreting rates upto 5000 cu.yds. per day have been attained in some cases. This

has been made possible by the appropriate use of belt conveyors, automatic batching plants, trestles and cranes or cableways. The 3050 ft. long 20 ton cableway used at Rihand for concrete placement is particularly worth mentioning. Natural aggregates suitable for concrete construction were available only in one or two of these dams. In an extreme case like Rihand, the entire aggregate and even most of the sand had to be processed for quarried rock.

8. Mass concrete placed at a rapid rate brings in the problem of temperature control to avoid high temperature stresses and consequent cracking of the dam. Precooling of the aggregates and postcooling of the placed concrete have been used individually or in conjunction according to actual requirements. Precooling was resorted to in Vaitarna, Rihand and Koyna dams while both pre and post cooling was used in the 740 ft. high Bhakra Dam.

9. Another means of controlling temperature is the reduction of the cement content in concrete. 15% to 25% reduction of cement content has been achieved by the admixture of indigenously manufactured pozollanas. Burnt brick powder, calcined shales and fly ash are some of the pozallanas successfully used. Advantage has also been taken of the favourable effect of adding air entraining agents.

10. The practice of providing plan transverse contraction joints at regular intervals is normally followed. However, shear keys and arrangement for grouting such joints have been made at Bhakra Dam so that a certain portion of load is transferred to the abutment by twist and horizontal bending action.

11. Rubble masonry has been preferred to concrete at many sites. Rubble masonry construction employs a large labour force with a high proportion of unskilled workmen and requires less mechanisation and is, therefore, suited to local conditions. This has led to its adoption wherever it is consistent with the required rate of progress, which in turn depends on working space. However, some diffidence about its use on high dams existed, as no strength tests had been conducted on masonry. The mortar strength used to be taken as the limiting strength of masonry. Since the individual stones are large, testing machines of the capacity required for testing the large size specimens of masonry were not available. A compression testing rig of four and a half million pounds capacity was improvised at Hirakud Laboratory. The equipment was set up in a niche in a quarry face. The force in this test was provided by four 500 ton hydraulic jacks reacting against the roof and floor of the niche. Test results showed that rubble masonry in 1:3 concrete mortar can give crushing strengths of the order of 2500 to 3000 lbs. in 28 days. These tests have made it possible to use rubble masonry for the 370 ft. high Nagarjunasagar dam, of which the lower portions were originally specified to be done in concrete.

12. When rubble masonry is used for higher dams it is necessary to use labour and mechanisation in a judicious combination. In this case the transport of stones and mortar have to be mechanised especially at higher elevations. Trestles, rail cars, cranes, monotowers have been used for this purpose.

13. The spillway and energy dissipating devices are invariably tested on hydraulic models. Large size sluices are also used in addition to overfall spillways for discharging the floods and also as outlets for released. Sizes upto 12 feet by 22 feet operating under heads 100 feet and more have been used. The design of such sluices have been based on extensive hydraulic model experiments.

14. Photoelastic methods have been employed to determine stresses in concrete and masonry structures. Reinforcements around large size openings, treatment of weak foundation strata, and stresses in spillway training walls are some of the problems solved by this method. The conclusions have often been confirmed by solution of stress functions by relaxation methods.

15. In the field of earth dam construction, organised heavy earth moving equipment is generally employed. Good quality control and rapid rates of progress have been achieved, for example, at Hirakud Dam involving a volume of 24 million cubic yards of earth work. In order to achieve efficient and economic use of the equipment, regional training centres for earth-moving equipment operators, mechanics and foremen have been established.

16. Foundation treatments for concrete and masonry dams on rocks conform to accepted practices namely, consolidation grouting and a fairly deep impervious grout curtain. In earth dams, on other than rock foundations, a positive cutoff into impervious strata is preferred, usually by means of cutoff trenches. Where excavation for deep cutoffs has not been possible, due to high permeability and consequent dewatering problems, clay, cement or chemical grouting is now resorted to. A recent example is at Kotah earth dam where a grout curtain upto 60 feet depth has been constructed in a foundation consisting of sand and boulders with some lenses of clay. Clay, cement and sodium silicate were mixed in varying proportions for the grout.

## HYDRO ELECTRIC POWER STATIONS

17. In a country where fuel resources are concentrated in a few regions, and further restricted by inadequate transport facilities hydropower generally becomes the cheapest source of power. Moreover, a relatively large portion of cost of generation can be met from indigenous materials and labour. Many of First and Second Five Year Plan Projects were conceived as multipurpose projects and considerable power generation at the dams was envisaged. Though some limitation to this type of development is inevitable due to the seasonal pattern of releases of water for irrigation, co-ordinated operation on grid with other power stations, having storages not tied up with irrigation patterns is resorted to.

18. The modern trend towards the use of largest sized machines consistent with efficient operation of stations in a growing load pattern and transport facilities available, is followed. Thus at Bhakra, 90,000 KW units have been installed

for the Left Bank Power House, and 120,000 KW units are being obtained for the Right Bank Power House. Ultimate installed capacities are designed with a view to future peaking operation that may be necessary for co-ordination with thermal and nuclear stations which have also been envisaged. Underground power stations have been adopted when they proved more economical on the basis of penstock cost, capitalised annual charges or increased power for the same or less cost. Koyna(240,000 KW), Maithon (60,000 KW) are such examples. Where the use of mild steel for penstocks resulted in excessive thickness, high tensile steel has been used instead. The Power House designs follow conventional methods.

19. Excavation below ground water level in pervious foundations has been done by the well point system of dewatering. Depths upto 60 feet below ground water level have been excavated by this method. Excavation problems are further reduced by the introduction of tubular turbines which are being considered for some of the recent projects. The use of tubular turbines will result in economy in the cost of power house structure as well.

CANALS

20. In canal work, the excavation is semi-mechanised. Generally heavy excavating equipment like draglines, etc. have been adopted in main canal excavation, but the branches and field channels are still largely hand excavated. Lining construction and design is largely influenced by availability of materials, labour etc. locally. Thus brick and tiles have been used where materials for concrete or the requisite machinery are not readily available. The biggest single use of tile lining is in the Rajasthan Canal having a head discharge of 20,000 cusecs and a length of 425 miles.

PRESTRESSED CONCRETE

21. Prestressed concrete will be increasingly used in the field of surface water utilisation. Examples of the utilisation are the strengthening of Tansa Dam in Bombay by means of prestressed cables anchored into the foundation rock, the Kunu Syphon, where 20 feet diameter prestressed concrete syphon pipe, 6000 feet long under a hydrostatic pressure of 85 feet carries canal waters across Kunu river.

INVESTIGATIONS

22. One of the greatest retarding factors in the rapid construction of structures for surface water utilisation is lack of surveys, topographical and hydrographic. To mitigate the delays due to this factor, Reservoir Surveys are now done with the help of aerial photography. Automatic rainfall recording stations are now used at inaccessible locations. Automatic water level recorders, and even radio operated water level gauges have been employed. In the field of instrumentation continuous research is being conducted for improving techniques for making hydraulic measurements. As an illustration, the big flood

discharge of Mutha river was gauged by the Central Water and Power Commission in collaboration with Atomic Energy Commission by use of Radio Isotopes and some promising results obtained. Radio Isotopes have also been used as tracers for sediment movements. In this field the techniques of Fluorescent tracer has great scope since the hazards connected with radio isotopes are avoided and also because of the difficulty of obtaining radio isotopes in underdeveloped countries.

ORGANISATION

23. The planning for utilisation of surface water has to be done in a basinwise or preferably on a regionwise basis for maximum benefit. Recognising this, the Central Water and Power Commission is responsible for initiating, co-ordinating and furthering river valley projects in the country. The constitution makes the Central Government responsible for proper regulation and development of interstate rivers and river valleys to the extent considered by Parliament, to be necessary in the Public interest. In conformity with the above responsibility, two Acts namely, Inter-state Dispute Act, 1956 and River Board Act 1956, have been passed. The first provides for adjudication of disputes relating to utilisation of interstate rivers and river valleys and the second for regulation and development of inter-state rivers and their valleys. Projects falling entirely within a State are being planned and constructed by the concerned State itself.

24. In the field of research, the activities of various hydraulic research institutions are co-ordinated by the Central Board of Irrigation and Power, so that there is no duplication of research programmes.

25. The Library and Information Bureau of the Central Water and Power Commission renders valuable service by providing a comprehensive collection of books and through its technical abstracts.

OUTLOOK FOR THE FUTURE

26. The experience and momentum gained in the first two five year plans are being put to beneficial use in implementing the third and fourth plan projects. It is hoped that the major and medium projects alone will provide irrigation facilities to an additional 46 million acres by the end of the fourth plan, as compared to the 22 million acres of the pre-plan period. The corresponding increase in the installed capacity for hydro-power generation will be about 11 million kilowatts. This would amount only to about 25% exploitation of the available hydro potential and there will still be plenty of scope for further development.



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